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BRAZING METHOD AND APPRATUS

Abstract:

Abstract of GB1332523

1332523 Brazing; making honeycomb panels; stamping AERONCA Inc 7 Jan 1971 [7 Jan 1970] 881/71 Headings B3A B3Q and B3R [Also in Division H5] Two face sheets 11, 12 and a honeycomb core 13 are brazed together to form a sandwich panel for e.g., supersonic speed aircraft and space vehicles, by successively (i) initially tack welding or tack brazing the sheets and core together to form an assembly 10, (ii) disposing the assembly between upper and lower ceramic dies 32, 33, (iii) raising the assembly to brazing temperature by resistance heating elements interposed between the assembly and the dies, (iv) compressing the assembly between the dies and, finally, (v) cooling the brazed assembly by gas blown through openings in the working faces of the dies. The brazing may be effected in hard vacuum or in an inert (e.g. argon) atmosphere at sub-atmospheric pressure. The face sheets and core may be of stainless steel or heat-resisting nickel alloy, the core being formed as by spot welding together corrugated strips. Brazing alloy, such as 23% Mn, 4% Cu, 2% Si, 71% Ni; is applied to the core edges as by dipping in or spraying with a brazed powder or the alloy may be in the form of interposed thin sheets. The process may be applied to the brazing of planar or, as shown, curved panels, The process may also be used to finish curved shape, by hot creeping, tacked assemblies of planar or lesser curvature configuration. Apparatus.-The upper and lower dies 32, 33 are respectively fast and vertically slidable in half-housings 15, 16 fastenable together by screw C-clamps 26 and flange sealed by an O-ring 24. Argon entry and vacuum lines 73, 75 are con- nected to the half-housing 16. Workpiece cooling gas (pre-chilled argon) is directed through upper and lower lines 67 and manifolds 42, and longitudinal passages 41, 58 and transverse openings 43, 71 in the dies 32, 33. The die working faces may be smooth or networked with grooves communicating with the openings 43. A lower inflatable (e.g. fabric or stainless steel) bag 48 is disposed between the lower die 33 and the half housing 16 and connected to a line 77. The resistance heating elements comprise strips 81, 83 connected between bus-bars 78, 80, 82 which are connected to power cables 77 and preferably supported by tension springs 79. Local heater cooling for temperature uniformity across the assembly 10 may be achieved by cooling water pipes adjacent the bus-bars (Fig. 10, not shown) or, as shown, by an electron emission cooling circuit comprising probes 84 positioned adjacent the bus-bars and so connec- ted to high voltage D.C. that, on completion of a circuit to a probe, electrons are emitted from a bus-bar to probe, monitoring being effected by thermocouples. An upper, e.g. stainless steel, welded bag 90, sized to suit the assembly 10, is, in use, disposed between the upper die 32 and the upper face sheet 12. Water vapour in the housing 15, 16 is trapped on the wall on a cold well (Fig. 8, not shown) which contains e.g., liquid nitrogen and is connected to the housing. The housing half 15 is raiseable as by a pulley and rope 18. Operational steps: (1) An insulating blanket 100, the lower

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DRAWINGS ATTACHED

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(54) BRAZING METHOD AND APPARATUS

(71) We, AERONCA, INC., a Corporation organised and existing under the laws of the State of Ohio, United States of America, of 1712 Germantown Road, Middletown, Ohio 45042, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a new and improved method and apparatus of brazing composite honeycomb core panels.

The present invention is particularly useful in connection with the brazing of stainless steel honeycomb panels of the type utilized in the construction of for example, supersonic speed aircraft and space vehicles. Panels of this type are subjected to high temperature during use and, accordingly, are formed from stainless steel surface sheets brazed to the opposite sides of a centre honeycomb core, formed of stainless steel. These panels are manufactured to meet high structural requirements with the result that the brazed joints must be substantially flawless.

Those techniques in present use which have been practical enough to produce the high quality panels required have been very expensive and time consuming.

According to the invention there is provided a method of brazing a honeycomb core sandwich member which comprises two outer skin sheets and an inner honeycomb core, a brazing alloy having been interposed between the skin sheets and the honeycomb core, comprising heating the sandwich member between two co-operating dies to brazing temperature by means of resistance heating elements interposed between the sandwich member and the two dies, inflating an expandable bag to effect movement of one die towards the other die to cause the two dies and sandwich member to seat relative one another, and then compressing the sandwich member between the two dies, thereafter cooling the brazed sandwich member by means of a gas blown outwards through openings in the working faces of the dies.

Also according to the invention there is provided an apparatus for brazing a honeycomb core sandwich member which has two outer skin sheets and an inner honeycomb core, comprising two individual die members having opposed working faces between which the sandwich member can be compressed, resistance heating elements arranged to be interposed between the sandwich member and the two dies for heating the sandwich member to brazing temperature, means for compressing the sandwich member between the dies, means for providing an inert atmosphere around the sandwich member when heated, and an expandable bag to effect movement of one die towards the other die to cause the two dies and sandwich member to seat relative one another, the said one die being movably mounted for movement towards the opposite die and each of the dies having a plurality of openings in its working face out of which cooling gas can be passed to cool the sandwich member.

The method and apparatus of our invention enable honeycomb core sandwich structures to be brazed at a substantial reduction in cost and in substantially less time than was possible with previous methods. The utilization of the present method and apparatus also facilitates the production of superior honeycomb structural members having improved brazed joints and surface characteristics, e.g. lack of wrinkling and the like.

According to one embodiment, the brazing apparatus of the present invention includes a two-piece, box-like cold wall enclosure. The enclosure consists of upper and lower sections with mating peripheral flanges. During a brazing operation the sections are clamped together and an airtight joint is formed by an O-ring carried by one of the flanges and compressed into sealed relationship with the opposite

flange. Each housing section carries a cast stable die member preferably formed of a suitable ceramic, such as Glassrock. Means are provided for raising the upper housing member and its die an appreciable distance above the lower housing member so that easy access is provided to both die members and the interior of the housing. This greatly facilitates the setting up of the tool, and loading and unloading of the honeycomb panel being brazed.

Each die member has a working face and a plurality of internal coolant passages which communicate with the face through a plurality of small ports. The coolant passages of each die are interconnected through a manifold to a cooling gas line. In the preferred embodiment the lower die can be shifted within the housing toward and away from the upper die. These movements are effected by means of an inflatable bag mounted beneath the lower die between that die and the bottom wall of the lower housing.

The workpiece is heated by means of electrical resistance heater strips which extend transversely between the workpiece and the upper and lower die members respectively. A second pressure bag is disposed between the upper heater strips and the upper surface of the sandwich structure. This upper bag conforms itself to the configuration of the upper die and when inflated is effective to apply a substantially uniform pressure normal to the surface of the sandwich structure no matter whether that surface is planar or curved.

The apparatus also includes a connection to a vacuum pump and a connection to a source of inert gas, such as argon. Although it is preferable to carry out the brazing operation in an inert atmosphere, such as argon, the present apparatus can also be utilized to carry out a brazing operation under a hard vacuum. In accordance with one aspect of the present invention, the amount of moisture within the enclosure is minimized by means of a cold trap which communicates with the housing and includes an airtight chamber at least one wall of which is common with a well containing a cold material, such as liquid nitrogen. The gas within the tank is circulated through the chamber where water vapour is condensed and freezes on the cold wall. This vapour is thus held away from the sandwich material being brazed.

One of the principal advantages of this apparatus is that it facilitates the utilization of a very rapid brazing cycle. For example, in a typical brazing operation the brazing apparatus can be loaded in approximately 15 minutes. The enclosure can be purged and backfilled with an inert gas and the part brought up to brazing temperature in one hour. Thereafter, the brazed part can be directly cooled in one hour by introducing a cooling gas, such as chilled argon, through the apertures in the die. This two hour cycle is approximately one-seventh the length of time required in a conventional brazing operation. Moreover, the savings in labour and expendable materials can run as high as 74% for a given part.

The sandwich structure to be brazed is placed over the lower die member. This die member has previously been covered with an insulating blanket, resistance heater strips and other conventional elements, such as slip sheets and the like. A slip sheet and inflatable bag are placed above the sandwich member and are then covered with resistance heating strips, an insulating sheet and blanket. The upper housing member is then lowered and clamped to the lower housing member to form an airtight closure around the dies. Both the upper bag above the sandwich and the lower bag below the lower die are evacuated. The enclosure itself it then evacuated and back-filled with argon. This may be repeated one or more times.

In the preferred method, after the final back-filling of argon to a pressure of the order of 5″ of mercury, the temperature of the workpiece is raised by the resistance heaters to brazing temperature. The lower bag is then inflated to raise the lower die. This causes the die members and workpiece to seat relative to one another. Thereafter, the upper bag is inflated to apply a uniform brazing force normal to the surface of the sandwich structure.

After the brazing has been completed, the electrical resistance heaters are deenergized and the pressure bags are again evacuated. A cooling gas, such as chilled argon, is introduced through the passageways in the dies. The cooling gas issuing from the bottom die is effective to lift the panel from the bottom die so that the panel in effect is suspended and immersed in a stream of cooling gas. After the panel temperature has been reduced by the desired amount, the top housing section and its attached die member are raised and the brazed structure is withdrawn.

In addition to the economics provided, this method is advantageous in that it results in the production of a superior brazed panel member. In the first place, the rapid elevation of the sandwich member to brazing temperature and rapid cooling thereafter minimizes any tendency of the brazing alloy to migrate or separate. Secondly, the sandwich structure is not subjected to any appreciable pressure during the time when it is being brought up to brazing temperature. Thus, the skin is kept smooth and free from wrinkles. Moreover, the brazed joint is uniform since the parts have been subjected to a uniform pressure across their entire surface.

Moreover, the brazed joint is also made uniform because the temperature across the honeycomb structure is kept substantially uniform. This uniform temperature is main-

tained by effecting a local cooling adjacent to one or more edges of the honeycomb structure which would otherwise develop hot spots. This local cooling action is obtained either by causing an emission of electrons from the electrical heating means in this area or by causing radiation of heat from the electric heating means in this area to a sink in the form of a tube through which cooling water is fed when cooling is required.

A sandwich structure can be creep formed simultaneously with the brazing operation. More particularly, a sandwich structure which is to be given a curved configuration is not completely pre-formed prior to the brazing operation, but is either inserted between the dies in a planar condition or in only a partially curved condition. The pressure exerted upon the structure when it is at the brazing temperature by the upper pressure bag not only causes the formation of a braze joint, but also bends the sandwich into its final shape conforming to that the die faces.

The invention will now be illustrated with reference to the accompanying drawings illustrating the manner in which the present process is carried out and a preferred form of apparatus for practicing the process.

In the drawings:

Figure 1 is a perspective view, partially broken away, of a typical honeycomb core member fabricated in accordance with the principles of the present invention.

Figure 2 is a perspective view of a preferred form of brazing apparatus for carrying out the present brazing method.

Figure 3 is a transverse cross-sectional view of the brazing apparatus with the top in a lowered position. The view is taken generally along line 3—3 of Figure 2 (except that the top is lowered and the lower bag is inflated).

Figure 4 is a cross-sectional view similar to Figure 3 with the lower bag deflated.

Figure 5 is a semi-diagrammatic perspective view of one form of core heating and temperature control unit.

Figure 6 is an enlarged, generally diagrammatic, partially exploded, cross-sectional view taken through the upper and lower die members, the sandwich panel being fabricated, and through the heater strips.

Figure 7 is a cross-sectional view taken along line 7—7 of Figure 2 showing a clamp for securing the upper and lower housing members together.

Figure 8 is a diagrammatic view of a vapour trap utilized in connection with the present brazing apparatus.

Figure 9 is an end view of the brazing apparatus of Figure 2.

Figure 10 is a diagrammatic view illustrating a modified form of temperature control.

The present apparatus is used in the fabrication of honeycomb sandwich structures. One such honeycomb sandwich panel 10 is shown in Figure 1. This panel comprises two outer skin sheets, or faces, 11 and 12 and an inner honeycomb core 13. The skins, or faces, 11 and 12 in a typical structure are formed from sheets such as stainless steel or Inconel (Registered Trade Mark). The honeycomb core is likewise formed from a thin metal foil of the order of, for example, .002" thick.

The core is pre-formed using any suitable technique, such as spot welding together adjacent corrugated strips along their abutting nodal portions. The honeycomb core and panels are joined together by a suitable braze alloy comprising, for example, 23% manganese, 4% copper, 2% silicon and 71% nickel. The braze alloy can be applied to the exposed edges of the honeycomb core in any suitable manner, such as by dipping the core in a braze powder, by spraying the core with a powder, or by utilizing the braze alloy in the form of thin sheets interposed between the core and skin sheets. It is to be understood that while the present method can be utilized to great advantage in the brazing of compound curved panels, such as the panel shown in Figure 1, it can also be used in the fabrication of simply curved panels or planar panels.

The overall construction of the brazing apparatus 14 is best shown in Figures 2, 3 and 9. As there shown, the brazing apparatus 14 comprises a cold wall, box-like, airtight exterior housing consisting of upper section 15 and lower section 16. Lower housing member 16 is stationary and is mounted upon a suitable base 17. The upper housing is adapted to be raised and lowered relative to the lower housing member 16 by any suitable form of elevating mechanism, such as the counterweight, rope and pulley arrangement 18 shown diagrammatically in Figure 9.

When upper housing 15 is in its elevated or storage position as indicated in Figure 9, it is spaced an appreciable distance from lower housing 16, allowing ready access to the elements disposed within both the upper and lower housing sections. In its operative position, however, the upper housing is lowered into sealed engagement with lower housing 16. This sealed engagement is provided by outwardly extending peripheral flanges 20 and 21 formed upon the upper and lower housing members 15 and 16 respecitvely.

As is best shown in Figure 2, the housings are brought into precise alignment by the interengagement of upstanding locating pins 22 carried by lower flange 21 and aligned openings 23 formed in upper flange 20. The lower flange also carries an O-ring 24 which extends completely around the flange in a peripheral channel 25. When the upper flange 20 is clamped against the channel 25 of lower flange 21 as indicated by the dotted lines in Figure 7, O-ring 24 is compressed to provide

a completely airtight seal around the entire periphery of the mating upper and lower flanges 20 and 21.

The clamping force for holding the upper and lower housing together is provided by a series of clamp mechanisms 26 as shown in Figures 2 and 7. Each clamp mechanism comprises a generally C-shaped clamp arm 27 pivotally mounted on a pivot pin 28 beneath lower flange 21. The upper end of the C-clamp carries a clamp screw 30 having a handle 31 and a clamp foot 29 adapted to press against the upper flange 20 to force that flange into tight engagement with the lower flange 21.

The upper and lower housing members 15 and 16 each respectively carry ceramic die members 32 and 33. These die members are preferably formed of a suitable dimensionally stable ceramic material, such as Glassrock. The die members are movable relative to one another within the confines of the outer hous-members 15 and 16 respectively.

More particularly, in the specific embodiment shown, upper die member 32 is rigidly mounted within upper housing member 15. As shown in Figure 3, upper die member 32 includes upper, outwardly extending side flanges 34 which are engaged by Z-shaped angle members 35. These angle members are bolted to the upper portion of housing member 15 as by means of bolts 36 so that the upper surface 37 of the die member 32 is rigidly clamped in place against the top wall 38 of housing member 15.

Upper die member 32 includes a lower working face 40 having the contour of the upper surface of the sandwich section 10 being fabricated. The upper die section is further provided with a plurality of longitudinally extending coolant fluid passageways 41 adapted to be connected to an upper manifold and supply tube (not shown), but generally like the lower manifold 42 and tube 67 shown in Figure 2. Bores 41 extend from one end of the upper die member to substantially the opposite end of the die member. Each of these passageways is connected to a plurality of small ports 43 which extend from the core to the working face 40 of the die. In the embodiment shown, this face is smooth. However, in some embodiments the face 40 can be provided with a network of longitudinal and transverse grooves. In this case, the ports 43 communicate with the grooves (not shown).

The lower die member 33 is mounted for limited vertical movement within lower housing member 16. More particularly, die member 33 includes a horizontal bottom wall 47 which is disposed in engagement with an inflatable bag 48 disposed between bottom surface 47 of the die member and bottom wall 50 of the lower housing member 16. Lower die member 33 also includes two opposed vertical side walls 51 and 52. These walls are constrained against lateral movement by means of stationary guide members 53 and 54. Each of the guide members as shown is in the form of an angle member having a bottom arm 55 welded or otherwise secured to the bottom wall 50 of the housing member and an upwardly extending arm 56 in engagement with one of the vertical walls 51 and 52 of the die member. Similar guide members (not shown) are provided for constraining endwise movement of the lower die member.

Lower die member 33 includes an arcuate working face 57 conforming to the configuration of the lower surface of braze composite 10. Die member 33 also is provided with a plurality of longitudinally extending coolant passages 58. These passages extend from one end wall 60 of the lower die adjacent to the opposite end wall 61 of the die. A connection is made to the coolant passages from a manifold 42. This manifold is joined to a tube 67 which extends through a side wall 70 of lower housing section 16.

Passages 58 interconnect with a plurality of small bores 71. These bores extend through to the working face 57 of the lower die member which, in the embodiment shown, is smooth but which alternatively may be provided with a plurality of longitudinal and tranverse grooves for distributing the coolant over the face of the working die.

As indicated above, lower die member 33 is adapted for vertical movement relative to the bottom wall 50 of the housing. This movement is effected by means of an inflatable bag member, or bladder, 48. In one preferred embodiment, bladder 48 is formed of neoprene-coated Dacron (Registered Trade Mark) fabric. Alternatively, this bladder can be fabricated from a thin flexible material, such as 321 stainless steel of a thickness of approximately .015″. Bag 48 is connected to a line 72 which extends from outside of the lower housing through a wall of the housing as shown in Figure 2.

In addition to these elements, the present tool includes a connection to an argon back-fill line 73 which communicates with the interior of the housing through side walls 74 (Figure 2). A vacuum line 75 is connected to the housing through side wall 70. It is to be understood that these and all other connections through the walls of housing sections 15 and 16 are airtight.

Another major component of the brazing apparatus is the electrical heating and temperature control system 76. Essentially, the electrical heating system comprises a plurality of power cables 77 which are connected to bus bars 78 and 80. Bus bar 78 is actually a two-piece clamp bar which is effected to clamp the ends of a plurality of heater strips 81.

These heater strips are formed of a suitable resistance heating material, such as .012″ chromel metal. The strips extend transversely of the die assembly generally parallel to one

another. At the opposite side of the die assembly the strips are joined to another bus bar 82. This second bus bar 82 is also secured to a plurality of lower heating strips 83 which are similar to the first set of strips and which pass beneath the lower portion of the assembly 10 being fabricated and the lower die section. These lower strips 83 are clamped to lower bus bar 80. It is to be understood that bus bars 78, 80 and 82 are preferably carried by tension springs 79 mounted on the side walls of housing member 16 in a conventional manner. Suitable electrical insulation is maintained.

It is to be understood that the power supply system for the electrical heating elements is provided with conventional controls for regulating the temperature developed by the resistance heating elements. However, in some cases it develops that the temperature is not uniform across the piece being brazed. Accordingly, means are provided for selectively lowering the temperature at one or more edge portions of the braze assembly.

In brazing pieces of the type shown in Figure 5, it has been empirically determined that hot spots tend to develop adjacent to the edges of the pieces. As shown in Figure 5, these edges are adapted to be selectively cooled by means of an electron emission cooling circuit. It is to be understood that thermocouples (not shown) are disposed at a plurality of points adjacent to the working faces of the die members so that the temperature of every area of the sandwich structure can be monitored continuously.

As shown in Figure 5, a plurality of probes 84 are permanently mounted within lower housing 16 and are electrically insulated therefrom. The probes are spaced closely adjacent to one or the other of the bus bars 78, 80 and 82. The probes are connected to a high voltage source of direct current, for example, a source of the order of 20—50 kg. The positive line 85 of this source is connected to the bus bar 78 while the negative leads 86 are connected to the probes 84 as indicated diagrammatically in Figure 5. When it is desired to cool one or more of the localized areas adjacent to one of the probes, the circuit is completed to that probe from the high voltage DC supply. As a result, electrons are emitted from the bus bar adjacent to the probe. This results in a loss of energy in that portion of the bus bar and manifests itself as a reduction in temperature. The temperature of the adjacent area of the workpiece being brazed is lowered by conduction through the adjacent heater strips to the cool spot on the bus bar.

A modified form of local cooling means is shown diagrammatically in Figure 10. As there shown, two tubes 110 and 111 extend parallel to bus bars 78 and 82 respectively. These tubes are connected through suitable valves to a source of water. When it is desired to cool one side or the other of the honeycomb sandwich structure, water is introduced into the tubes. The water flow maintains the temperature of the tubes at a relatively low level so that heat radiates from the adjacent bus bar to the tube. This reduces the temperature of the adjacent edge of the sandwich structure by an amount sufficient to reestablish a substantially uniform temperature across the sandwich.

In addition to these elements, the present brazing apparatus includes an upper, or hot, bladder 90 (see Figures 3, 4 and 6). This bladder is disposed between the upper die member and the upper skin 12 of the workpiece. The bladder is fabricated from thin sheets of stainless steel, or a similar heat resistant material, the thickness of the bladder sheets preferably being from .015" to .025". The two sheets comprising the bladder are welded around the entire periphery to form an airtight member. A connection is made from the bladder to an inlet line which passes through the top wall of housing section 15 and communicates with the interior of the bladder. In the present embodiment, bladder 90 is preferably fabricated so that its exterior dimensions correspond very closely to the exterior dimensions of the panel.

Another component of the present brazing apparatus is shown in Figure 8. As there shown, a vapour trap assembly 92 communicates with one corner of housing member 15. The vapour trap assembly includes a line 93 which opens through a suitable port in the housing and communicates with a valve 94. The opposite side of valve 94 is connected to an airtight chamber 95. Chamber 95 is a cold chamber which includes a hollow internal well 96. This well is open at the top and is connected to the external wall of the chamber 95 through a narrow neck portion 97 which functions to minimize the heat losses. The well is filled with an extremely cold material such as liquid nitrogen. The temperature of this material is so low that when valve 94 is opened and air circulates from the interior of the housing to the cold chamber, any water vapour condenses out of the atmosphere and freezes on the exterior surface of well 96. This is shown diagrammatically by the frozen vapour patch 98 in Figure 8.

In brazing parts utilizing the present method and apparatus, the first step is the fabrication of the upper and lower die forms 32 and 33. The working faces of these die forms are shaped and the longitudinal fluid passageways and ports are formed using conventional techniques. Then, upper die section 32 is mounted in upper housing 15 and lower die section 33 is mounted in lower housing section 16. Next, a pad of insulating cloth 100, such as a 3/4" thick blanket of Kaowool (Registered Trade Mark) material, is placed over the working face of lower die member 33. Then, the lower

resistance heater strips 83 are secured to bus bars 82 and 80 and are laid over the Kaowool blanket. An insulating sheet 101 formed of fibrous silica, or the like, is laid over the top of the heating strips 83. A heat distributing sheet of copper, or the like, 102 is placed over the top of the insulating sheet 101, and a slip sheet 99 of stainless steel is laid over the copper sheet.

Next, the sandwich assembly 10 is placed over slip sheet 99. It is to be understood that the core and two sandwich sheets 10 and 12 are temporarily adhered together by any suitable means, such as tack brazing or tack welding. After the sandwich assembly 10 is in place, a slip sheet 109 is placed over it and bag 90 is placed over the slip sheet. It is to be understood that the bag is not pressurized at this time. Thereafter, a copper sheet 103 is placed on top of the bag and is covered by an insulating sheet of silica fibres 104. Thereafter, the upper heating strips 81 are laid over the top of the insulating sheet and are secured to bus bars 82 and 78. The upper surfaces of the heating strips are covered by a second insulating blanket 105 formed of Kaowool or the like.

Following this procedure, the upper housing member 15 is lowered into contact with lower housing member 16. The clamps 26 are tightened down to compress O-ring 24 and establish a peripheral seal at a juncture of the upper and lower housing members.

In the next step, bags 90 and 48 are evacuated and the interior of the housing is evacuated by means of a vacuum pump connected to line 75. Following evacuation of the housing, the interior of the housing is back-filled with argon through feed line 73. This process of drawing a vacuum and back-filling can be repeated a number of times if desired. The function of the argon back-filling is to assist in flushing out the oxygen and water vapour in particular and in replacing it on the surface of all materials inside the braze tool. During this vacuum argon back-filling cycle, power is applied to the heating elements 81 and 83 to bring the temperature of the assembly to be brazed to approximately 500°F to thereby facilitate exchange of undesirable gas with argon as a surface layer. Following the purging, the interior of the housing is filled with argon to its normal working pressure of 5" of mercury. This pressure is accurately maintained by continuously supplying a small quantity of argon through line 73 while withdrawing a similar quantity of gas through vacuum line 75.

It is to be understood that during this time both upper bag 90 and lower bag 48 are held under vacuum. Thus, there is only a nominal force applied to the assembly being brazed and there is no constriction to cause wrinkling, i.e. the material can seek its proper position without wrinkling during the expansion phase.

After the interior of the housing has been placed under its operating pressure, the temperature of the part to be brazed is raised to brazing temperature, normally a temperature of the order of 1950°F. The total time required for the purging and back-filling operation and to bring the part up to braze temperature is of the order of one hour. As the work reaches brazing temperature, a pressure is applied to the interior of lower bag 48. This bag raises lower die member 33 and causes the part being brazed to generally accommodate itself to the working surfaces of the lower and upper die.

Pressure is then applied to upper bag 90. This pressure of from 1/2 to 3 psi results in a brazing force being applied normal to the surface of the part being brazed and of substantially equal magnitude over the entire surface.

After the core has been held at brazing temperature a sufficient length of time to effect a brazing operation, the electrical resistance heaters are deenergized, and the upper and lower bags are evacuated. This causes the lower die section 33 to be lowered. At the same time, pre-chilled argon is fed to the manifolds associated with the upper and lower die sections. This cold argon flows through the longitudinal passageways formed in each die member and escapes through the ports 43 and 71. The upper and lower die sections are thus separated and the cooling gas is forced through the many ports indirectly against the undersurface of copper sheet 102 and the upper surface of sheet 103. This causes brazed member 10 to be lifted off the lower tool and, in effect, causes it to float essentially between layers of coolant gas.

As a result of this action, the part is cooled rapidly, for example, from a brazing temperature of 1950°F to a temperature of 650°F in one hour. Thus, the total tool operating time from the point at which upper and lower sections 15 and 16 are closed to the time that the part is cooled to handling temperature is a total of two hours. The part is readily unloaded by merely disconnecting the upper clamp bus bar 78, and raising the top housing section and its attached die member.

It has been determined that parts brazed in accordance with this method are superior to parts brazed by conventional techniques in that they are less susceptible to wrinkling or distortion and, moreover, are possessed of a good, substantially uniform brazed joint.

In a modification of the process described above, a honeycomb core sandwich structure can be shaped to a final simple or compound curved configuration at the same time that the structure is brazed. More particularly, in practicing this modified process, the core and skin sheets constituting the panel assembly are tacked together either in a planar configura-

tion or in a lesser curvature than that of the final configuration. This panel assembly is placed on the lower die and is brazed in accordance with the process described above. In this case, however, when the final pressure is applied to the panel by upper bag member 90 after the panel has been raised to brazing temperature, the panel is not only brazed but undergoes hot creep forming which causes the panel to be shaped to its final configuration.

WHAT WE CLAIM IS:—

1. A method of brazing a honeycomb core sandwich member which comprises two outer skin sheets and an inner honeycomb core, a brazing alloy having been interposed between the skin sheets and the honeycomb core, comprising heating the sandwich member between two cooperating dies to brazing temperature by means of resistance heating elements interposed between the sandwich member and the two dies, inflating an expandable bag to effect movement of one die towards the other die to cause the two dies and sandwich member to seat relative one another, and then compressing the sandwich member between the two dies, thereafter cooling the brazed sandwich member by means of a gas blown outwards through openings in the working faces of the dies.

2. A method as claimed in any preceding claim in which one of the dies is positioned above the other.

3. A method as claimed in claim 1 in which the gas passes through passageways in each of the dies, the passageways being connected to the openings in the working faces.

4. A method as claimed in claim 1 in which the dies and sandwich members are enclosed in an airtight enclosure.

5. A method as claimed in claim 4 in which the sandwich member is heated to a temperature below brazing temperature by means of the resistance heating elements, the enclosure is evacuated, and then the enclosure is backfilled with an inert gas at a pressure less than atmospheric before heating to brazing temperature.

6. A method as claimed in any preceding claim in which the compressive force is applied normal to the surface of the sandwich member.

7. A method as claimed in any preceding claim in which the compressive force is applied by inflating an expandable bag member interposed between the sandwich member and one of the dies.

8. A method as claimed in any preceding claim in which a substantially uniform temperature is maintained in the sandwich member by effecting localised cooling of the resistance heating element at one end of the sandwich member.

9. A method as claimed in claim 8 in which the cooling is effected by causing electrons to be emitted from a portion of the resistance heating elements.

10. A method as claimed in claim 8 in which the localised cooling is effected by creating a flow of cooling water adjacent to the resistance heating means, heat being radiated therefrom.

11. A method as claimed in any preceding claim in which the dies are separated during the introduction of the cooling gas and the sandwich member forced from one die by cooling gas and is surrounded by cooling gas.

12. A method as claimed in any preceding claim in which vapour is removed from the brazing environment by exposing the gas forming the environment to a cold surface remote from the sandwich member, the vapour being condensed on the cold surface and thus being held remote from the sandwich member.

13. A method as claimed in any preceding claim in which the sandwich member has a configuration other than the final configuration, and in which the compressive force is applied normal to the surface of the sandwich member to creep form the sandwich member to its final configuration.

14. A method of brazing a honeycomb sandwich member substantially as herein described with reference to Figures 2, 3, 4 and 6 or Figures 2, 3, 4, 6 and 9 as modified by Figures 5, 7, 8 and 10.

15. An apparatus for brazing a honeycomb core sandwich member which has two outer skin sheets and an inner honeycomb core, comprising two individual die members having opposed working faces between which the sandwich member can be compressed, resistance heating elements arranged to be interposed between the sandwich member and the two dies for heating the sandwich member to brazing temperature, means for compressing the sandwich member between the dies, means for providing an inert atmosphere around the sandwich member when heated, and an expandable bag to effect movement of one die towards the other die to cause the two dies and sandwich member to seat relative one another, the said one die being movably mounted for movement towards the opposite die and each of the dies having a plurality of openings in its working face out of which cooling gas can be passed to cool the sandwich member.

16. An apparatus as claimed in claim 15 in which each die is positioned in its own box-like enclosure and one of the dies and its associated box-like enclosure is placed above the other die and its associated box-like enclosure.

17. An apparatus as claimed in claim 15 or claim 16 in which the dies contain a plurality of passageways connected to the openings in the faces of the dies.

18. An apparatus as claimed in any of claims 15 to 17 in which the dies are enclosed in box-like enclosures having peripheral flanges to enable the two enclosures to be engaged to define an enclosed region to which inert gas can be supplied to place the dies and any

sandwich member positioned between the dies in the inert atmosphere.

19. An apparatus as claimed in claim 18 in which the box-like enclosures have clamping means for holding the flanges in sealing airtight relationship.

20. An apparatus as claimed in any of claims 15 to 19 comprising means for selectively evacuating and pressurizing the expandable bag.

21. An apparatus as claimed in any of claims 16 to 20 in which the box-like enclosures are capable of being evacuated and having inert gas introduced thereinto after evacuation.

22. An apparatus as claimed in any of claims 17 to 21 comprising a means for introducing the cooling gas into the passageways and openings in each of the die sections.

23. An apparatus as claimed in any of claims 15 to 22 in which the means for compressing the sandwich member between the dies is a further expandable bag which is arranged to be interposed between one of the dies and the sandwich member to be brazed, this bag assuming a configuration conforming to the adjacent die face so that when the dies have been brought together and the expandable bag has been expanded the sandwich member can be placed in compression by a force normal to the surface of the sandwich member.

24. An apparatus as claimed in any of claims 16 to 23 comprising a cold trap having an airtight chamber in communication with the interior of the box-like enclosures and a well adapted to contain a cooling medium.

25. An apparatus as claimed in any of claims 16 to 24 in which the upper die is rigidly mounted within the upper box-like enclosure and the lower die is movably mounted relative to the lower box-like enclosure, a guide means being mounted within the lower section for restricting movements of the lower die to movements in a vertical direction, the expandable bag being interposed between the lower die member and the bottom wall of the lower box-like enclosure.

26. An apparatus as claimed in claim 24 or claim 25 in which the further expandable bag is interposed between the upper die and the sandwich member being brazed, the expandable bag having the configuration of the working face of the upper die.

27. An apparatus as claimed in any of claims 17 to 26 in which the passageways connected to the openings in the die faces extend longitudinally and for substantially the whole length of the die member, a manifold being interconnected to each of the passageways and each of the openings extending transversely from the passageways to the working face of the die.

28. An apparatus as claimed in any of claims 17 to 27 comprising means for effecting localized cooling of the edges of the sandwich member being brazed.

29. An apparatus as claimed in claim 28 in which the means for effecting localized cooling of the edges of the sandwich member being brazed comprises a probe adjacent to the resistance heating elements at the side of the member being brazed, a source of high DC potential, a means connecting the source of potential so that the probe is negative relative to the resistance heating means and electrons can be emitted from the resistance heating means to the probe in order to lower the temperature of the resistance heating elements in the area of the emission.

30. An apparatus as claimed in claim 28 in which the means for effecting localized cooling of the edges of the sandwich member being brazed comprise tubes adapted to carry cooling water adjacent to the resistance heating elements at the side of the sandwich member being brazed.

31. An apparatus for brazing a composite sandwich member according to claim 15 substantially as herein described with reference to figures 2, 3, 4 and 6, or figures 2, 3, 4, 6 and 9 as modified by figures 5, 7, 8 and 10.

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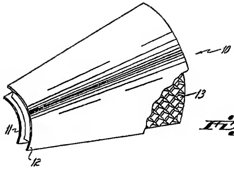
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Fig. 1

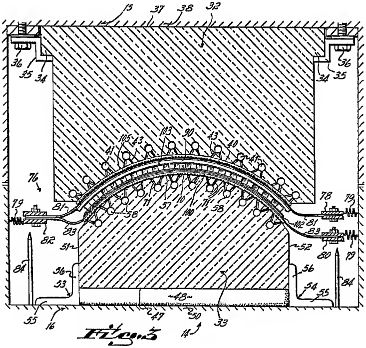
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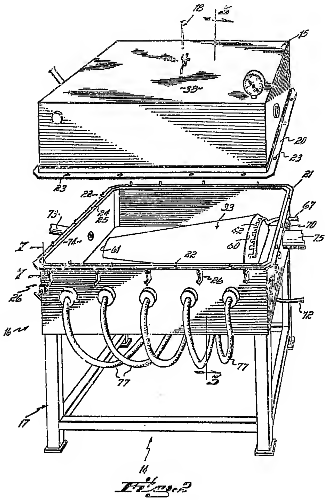
Fig. 3



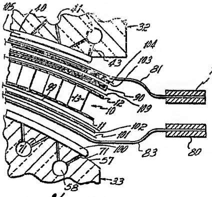


Fig. 6

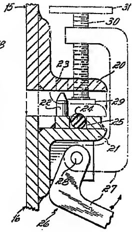


Fig. 7

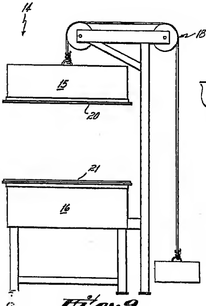


Fig. 9

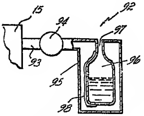


Fig. 8

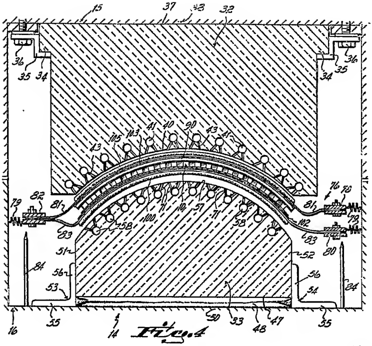


FIG.4

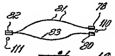


FIG.16

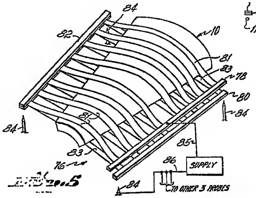


FIG.5